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METHODS AND MODELS FOR HADRON PHYSICS
Round Table

Panelists: C. Davies, S. Faccini, H. Lipkin, L. Maiani (Chair),
        F. J. Ynduráin
Contributors: C. Bugg, S. Eidelman, P. Faccioli, S. Glazek, Y. Glozman,
        E. Klempt, H. Koch, J. Lee-Franzini, R. Mussa, E. Pallante,
        S. Paul, K. Seth, U. Wiedner
Convenors: M. P. Lombardo, S. Miscetti, S. Pacetti

Abstract

A round table held during the Hadron07 Conference focusing on experimental observations of new hadronic states, on theoretical perspectives for their description, and on the role of hadronic spectroscopy in furthering our knowledge of the fundamental theory of strong interactions.

1 Opening Statements

<u>L. Maiani</u>

As I have already given the introductory review this morning, I will just invite Professor Ynduráin to begin, and Professor Davies and Doctor Faccini to continue after him. Which are the problems that you would like to put to the attention of the audience?

F. J. Ynduráin

Since, for obvious reasons of age, I imagined I was going to be the first panelist to talk, I have prepared a list of questions, experimental and theoretical, that I would like to have solved or, at least, understand them better.

1) We are all convinced that the particle η_b exists, but I for one will have nagging doubts until it is actually discovered. Particularly since there are sound theoretical calculations of its mass (some 35 MeV lighter than the upsilon), so one could check ideas in QCD for bound states. I am aware that this is not an easy experiment, but there you are.

2) One of the mysteries of QCD is the extent to which the *constituent* quark model works. I mean, it is OK to say that as quarks move in the soup of gluons and quark-antiquark pairs in a hadron they acquire an effective mass of some 300 MeV; but, except for the Goldstone mesons, this simple model works much better than what it should. For example, the relations of total cross sections

$$\sigma_{\pi\pi} : \sigma_{\pi N} : \sigma_{NN} = 2 \times 2 : 2 \times 3 : 3 \times 3,$$

$\sigma_{\pi N} = \sigma_{KN}$, etc. work at the level of 10%. Yet they are obtained assuming that hadrons consist of only constituent quarks, that behave as if they were free. These relations were obtained in the sixties of last century, and we are nowhere near understanding them; for example, they are contrary to what one finds in deep inelastic scattering, where hadron structure functions have a strong gluonic component.

3) We have a challenge in obtaining the pion-pion scattering amplitudes at low energy. Much improvement has been achieved recently, particularly for the S0 wave thanks to precise measurements of two-pion and three-pion kaon decays here at Frascati, and of K_{e4} decays by the NA48/2 collaboration. In this way, one can start to test predictions of chiral perturbation theory, and contribute to the construction of very precise $\pi\pi$ scattering amplitudes.

4) Of course, the resonances found in charmonium (the X, Y, Z_s) have shown a rich structure that ought to be investigated further.

5) (This in response to a question from the audience). I would like to remark that a much-publicised "discrepancy" between the pion form factor as measured in $e^+ e^- \to \pi\pi$ and in $\tau^- \to \nu \pi^- \pi^0$ is not incomprehensible nor does it pose a problem for incorporating $\tau^- \to \nu \pi^- \pi^0$ results into e.g., calculations of the muon $g - 2$. All one has to do is to take into account that the rho states

contributing there are different, ρ^0 in the first case and ρ^- in the second. And, because the rho contribution is so large (about a factor 50 at the peak) even a small mass and width difference between the two produces a large difference in the form factors. In fact, one can make the calculation and, once this effect is taken into account, the discrepancy between the pion form factor in $e^+e^- \to \pi\pi$ and in $\tau^- \to \nu\pi^-\pi^0$ is quite compatible with the systematic normalization uncertainties in these processes [see e.g. F. Jegerlehner, Proc. Int. Frascati Conf., 2003, hep-ph/0310234; S. Ghozzi and F. Jegerlehner, Phys. Lett. B **583**, 222 (2004); J. F. de Trocóniz, and F. J., Ynduráin, Phys. Rev. D **71**, 073008 (2005)].

H. Lipkin [1]

We still have a great deal to learn about how QCD makes hadrons out of quarks and gluons. We don't know enough about QCD to believe any hadron model. All the theoretical approaches including the lattice have drastic over-simplifications which leave us still far from our goal.

The following questions may lead to a better understanding of how hadrons are made from quarks and gluons.

1) What is the constituent quark picture? There are several versions.

2) Where does a particular version work very beautifully? Where does it not work so beautifully? Where does it not work at all?

3) Why?

Most theoretical treatments start with well defined models with a number of free parameters and try to use the data to fix the parameters. We look for clues in the data, for puzzles that challenge the conventional wisdom.

Our approach is very different from that of few-body nuclear physics which begins with a system of particles whose masses and interactions are assumed to be known. Our version of the constituent quark model begins with constituent quarks whose nature, masses and structures are not known, have an unknown dynamical origin, may differ between different hadrons and have so far not been explained by QCD. One challenge we face is how to use the new data on heavy quark hadrons to find clues to the nature, masses and structures of these constituent quarks.

Our quark masses are effective masses which contain contributions from

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[1]H. Lipkin could not participate and sent his contribution via e-mail.

complicated interactions in ways that are not understood. The fact that the same values for these effective quark masses are found in experimental masses of mesons and baryons is a striking challenge to all attempts to construct a more basic microscopic theory. This may indicate a new yet undiscovered symmetry or supersymmetry. We go far beyond conventional quark model investigations which use either a nonrelativistic or relativistic few-body model with fixed mass parameters. Lattice QCD has been so far unable to get the kinds of predictions between mesons and baryons that have been obtained with this phenomenological constituent quark model.

We start with experimental facts and surprising agreements from models with very simple assumptions. We want to find how maximum agreement with experiment can come from minimum assumptions.

A. Hadron Mass predictions and relations.

1) The simplest assumptions were first proposed by Sakharov and Zeldovich and later independently discovered by me. The hadron mass operator consists of (1) an effective quark mass containing all the spin-independent contributions including potential and kinetic energies. and (2) a two-body hyperfine interaction proportional to $\sigma_i \sigma_j$.

a) The difference between the effective mass contributions for any two flavors is the same for all ground state hadrons, both mesons and baryons.

b) The ratio between the hyperfine energies for any two combinations of flavors is the same for all ground state hadrons, mesons and baryons. The number of experimental regularities that follow from these simple assumptions is striking, and leads to the remarkable results in our paper hep-ph/0611306.

We compare a meson consisting of a valence quark of flavor i and a light quark system having the quantum numbers of a light antiquark with a baryon consisting of a valence quark of the same flavor i and a light quark system having the quantum numbers of a ud diquark of spin S. We make no assumption about the nature and structure of the valence quark or the light quark system. Our results apply not only to simple constituent quark models but also to parton models in which hadrons consist of valence current quarks and a sea of gluons and quark-antiquark pairs. When the hyperfine interaction between the quark and the antiquark or diquark is taken out (a simple procedure with no free parameters), the baryon-meson mass difference is independent of the flavor i of the quark which can be u, s, c or b. This alone is a striking challenge for QCD

treatments which so far have not found anything like this regularity between meson and baryon masses. These results can be seen in hep-ph/0611306.

2) The next version is that of DeRujula, Georgi and Glashow which assumes that the two-body hyperfine interaction is inversely proportional to the product of the two effective quark masses. The magnetic moments of the quarks are inversely proportional to same effective quark masses. This gives the remarkably successful predictions for the magnetic moments of the neutron, proton and Lambda and also some new mass relations.

B. Use of constituent quarks in weak decays.

Most treatment of weak decays assume that the weak transition is only between the valence quarks of the initial and final states. Quark diagrams are classified and assumptions are made like factorisation, etc. which neglect certain diagrams.

Here again I look for simple relations that work based on simple approximations like the following:

1) Charmless strange B decays are assumed to be dominated by the penguin diagram. The discovery of CP violation in these decays indicates that there must be some other amplitude that interferes with the penguin. In the limit where there is only a penguin contribution the four independent branching ratios for $B \to K\pi$ decays are all related and proportional to the penguin amplitude. We define three linear combinations of the four branching ratios which vanish if there is only the penguin contribution. Any linear combination differing from zero provides a clue to an additional contribution which interferes with the penguin. Before recent new more precise experimental data were available all three of these linear combinations were statistically consistent with zero. But new data show two of the three to be appreciably different, while one of them is still consistent with zero. If this is correct it tells us something about which contributions are producing the CP violation. It may imply a cancellation that makes one of these contributions vanish. We now need more and better data to check this out. It is on the Los Alamos Archive at hep-ph/0608284.

In vector-pseudoscalar charmless strange B decays like $K - \rho$ a phenomenological parity selection rule agrees surprisingly well with the data, but does not agree with simple models. But it comes from a simple description using hadron spectroscopy. The dominant penguin diagram produces a strange

antiquark, a u or d spectator quark, and gluons. In flavor SU(3) this state must be in an octet with the isospin and strangeness quantum numbers of a kaon. There are only two possible states with these quantum numbers, a normal kaon which is a quark-antiquark pair and an "exotic kaon" which has the opposite generalised charge conjugation and cannot be constructed from a single quark-antiquark pair. The data are consistent with a model which excludes the exotic kaon. This fits naturally into a picture where the strong interaction scattering producing the final state is dominated by intermediate resonances and these all have normal quantum numbers so the exotic contribution is suppressed. This is discussed in my paper hep-ph/0703191. But this exotic suppression ansatz does not make sense in the standard treatments which only assume states of two quark-antiquark pairs and no multiparticle intermediate states.

C. Davies

Lattice QCD is now able to calculate precise values for gold-plated hadron masses. These are summarised in the "ratio plot" of lattice QCD/experiment in my talk. Gold-plated means stable, well away from decay thresholds and accurately measured experimentally. For the calculations in lattice QCD that have been done so far there is excellent agreement with experiment when realistic sea quark effects are included in the calculation. This is after having fixed the 5 parameters of QCD for these calculations (4 quark masses and a coupling constant) from 5 other hadron masses. For example, D and D_s masses have been calculated, and agree with experiment, to 7 MeV. This level of accuracy would be impossible in any approximate model of QCD and is a very stringent test of the theory. So lattice QCD is now testing QCD. Most of the calculations have been done for mesons so far since they are easier. Gold-plated baryon masses will be calculated in the next few years and these will provide additional tests of QCD.

The masses of excited and unstable states are not nearly so easy to calculate. The precision possible from a lattice QCD calculation will not be as good. There are still interesting results to be had from doing the calculations, but you need to decide what question is being asked i.e. what level of precision is needed to answer it? You also then need to pay attention to the sources of systematic error in lattice calculations of these states.

One interesting lattice calculation underway is that of the baryon spec-

trum by the LHPC collaboration. The ground-state nucleon is gold-plated - the other states are not, and some are very broad and poorly known experimentally. A basic issue here is exactly how many states there are, and it is one that experimentalists are tackling. The LHPC collaboration is beginning preliminary tests on quenched gluon field configurations (i.e. not including the effects of sea quarks) of the kinds of operators, lattice volumes etc that they would need for a complete lattice calculation. They have obtained approximate masses for a lot of states, so it is encouraging news that this calculation is possible. The quenched results may be accurate enough (with, say, 20% systematic errors) to answer some of the interesting issues. On including sea quark effects, multihadron states in the spectrum will be an additional problem and it is not clear how well that can be tackled. It may obscure some of the masses you would like to extract even further and will certainly make quantitative analysis
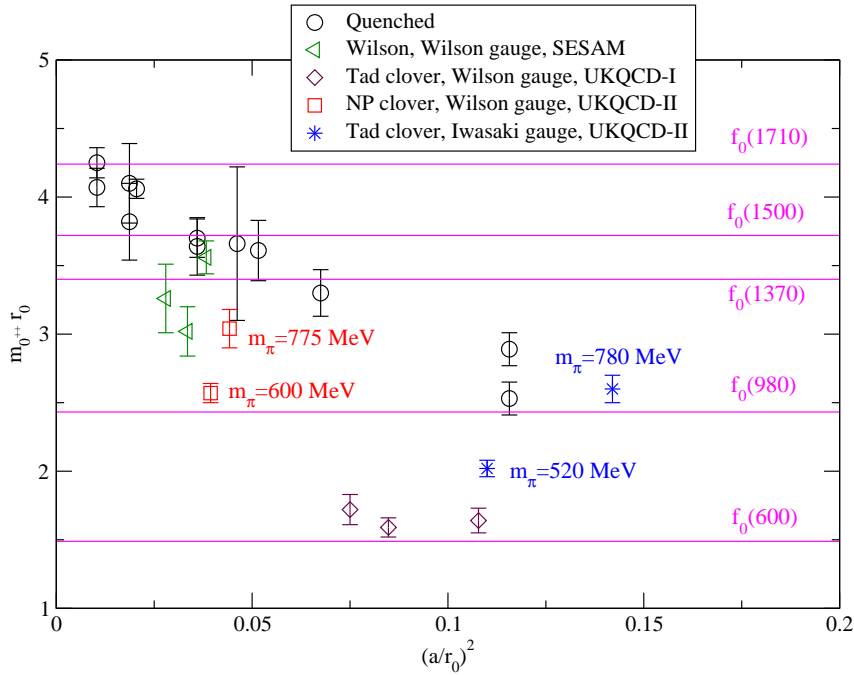

Figure 1: *Summary of unquenched results for lightest flavour singlet 0^{++} mesons, from McNeile, Lat07. The unquenched results are from SESAM, and UKQCD.*

Flavor singlet/glueball masses are even harder - see the plenary talk by C. Mc-Neile at LAT07, 0710.0985[hep-lat]. A summary of the lattice results contrasted with some experimental meson masses is reproduced below. The key to calculations in this area will be very high statistics, i.e. fast sea quark formalisms, and a good operator basis, so that all the mixing issues can be handled.

Summary

1) High precision results for gold-plated hadrons will continue to improve. These are the ones that provide the stringent tests of QCD because of the accuracy that is possible. For example, accurate simultaneous (i.e. with only one set of quark masses and coupling constant) calculations of heavy-heavy, heavy-light and light-light meson masses are now possible in lattice QCD and could not be done in any derived model of QCD.

2) This needs to be extended to gold-plated baryons and to 'silver-plated' mesons (particles that are unstable but relatively narrow like the phi, D* etc). Eventually there will also be results for higher-lying and more unstable particles. The same level of accuracy will not be possible, however.

3) The same remarks apply to electroweak decay rates. The gold-plated ones are those having at most one gold-plated hadron in the final state. We now have f_D and f_{D_s} to 2%. Calculations are in progress for $\Gamma_{e^+e^-}$ for J/ψ and ϕ. This is having a strong impact on the flavor physics programme. We also expect accurate form factors for semileptonic decay and structure function moments for baryons to be possible.

4) It is important to test lattice QCD with different quark formalisms and more results from a variety of formalisms will become available over the next few years.

<u>R. Faccini</u>

There are several areas where flavour physics can probe strong interactions and therefore verify or falsify models and lattice calculations:

- fits to the unitarity triangle parameters, $\bar{\rho}$ and $\bar{\eta}$. The current accuracy of the experimental measurements is such that the implications of the measurement of ϵ' in kaon decays is entirely dominated by the theoretical uncertainties and that the other quantities measured on the lattice can be overconstrained by other experimental measurements, if the Standard Model is assumed. This implies, as detailed in the dedicated publica-

tion [M. Bona *et al.* [UTfit Collaboration], JHEP **0610** (2006) 081], that before bringing a significant contribution to the unitarity triangle the measurements on lattice of f_{B_d} and f_{B_s} must improve by at least a factor three. On the other side the current measurements are still critical for the interpretations of the current data that include physics beyond the Standard Model.

- Semileptonic B, D and K decays. The best probes of QCD come in these systems where only two quarks interact. Inclusive measurements are particularly dependent on the availability of models that describe the data and can also be used to probe the parton-hadron duality assumed in all predictions. Exclusive measurements rely instead on the availability of the form factors. The statistics is high enough to allow the data to constraint the q^2 dependencies, and can therefore often discriminate among theoretical models that estimate the overall normalization.

- Most of the techniques to measure weak phases exploit the interference between amplitudes that have both weak and strong phases. The best environment to apply such techniques are the multibody decays, and their actual success depends on the possibility of properly modelling the strong phases of multibody decays. Several approaches have been developed in the past decades to take this problem (isobar model, K-Matrix,...) but there is still large arbitrariness in this kind of analyses. The field would profit from a systematic study that gives precise rules on the approach to follow and the resonances/poles to consider. There is an increasing wealth of experimental results of direct production of light mesons [see the contribution from C. Bini at this Conference] that must be used to support such a study.

- Heavy quarkonium spectroscopy. The spectroscopy of the bound states of a pair of heavy quarks can be predicted with relatively good accuracy with potential models [N. Brambilla *et al.* [Quarkonium working Group], hep-ph/0412158] This makes this field a good ground to observe new forms of aggregation. Indeed there have been recently a large number of experimental evidences that QCD does not only bind quark pairs but also groups of four quarks or of two quarks and gluons [Contribution from R. Mussa at Hadron'07 and from R. Faccini at Lepton Photon '07

(arXiv 0801.2679)].

The path towards the full understanding of the new spectroscopy is still long, both from the theoretical and the experimental point of view. In particular as far as the latter is concerned, only a very small fraction of possible final states and production mechanisms have been studied on the data available from B-Factories. Finally some of the measurements, in particular those implying D-meson reconstruction, will require a significantly larger statistics than what the current generation of experiments will collect.

The diagram below summarizes the current status

The observation matrix

	$J/\psi\pi^+\pi$	$D^{(*)}D^{(*)}$	$J/\psi\omega$	$J/\psi\pi^+\pi^0$	$\psi(2S)\pi$	$J/\psi K,\pi$	$\Psi(2S)\pi\pi$	$J/\psi\phi,\eta$	$J/\psi\gamma$
Notes	Mass range for B	Low stat	Only B dec	Mass range! No ISR	No ISR No π^0	No Search	No B-dec	Only B dec	Mass window
X(3872)	Seen	Seen	Not seen	Not seen	Not seen	No search	N/A	Not seen	Seen
Y(3940)	No search	X(3940)?	Seen	No search	Not seen	No search	No search	No Fit	No fit
Y(4260)	Seen	No fit	No fit	No search	No search	No search	Not seen	No fit	N/A
Y(4350)	Not seen	No fit	No fit	No search	No search	No search	Seen	No fit	N/A
Z(4430)	No search	No search	No fit	No search	Seen	No search	No search	No Fit	No search
Y(4660)	Not seen	No fit	No fit	No search	No search	No search	Seen	No Fit	N/A

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2 Discussion

<u>L. Maiani</u> We can now open the general discussion. It might be useful perhaps to divide the rest of the session in two, one devoted to experiments and the other to theory.

<u>K. Seth</u> I am an experimentalist and I have a question for the theorists. When Lattice came out we thought that experimentalists will soon be out of business. Now I feel our existence is not so much threatened, because now when I ask a question they occasionally reply that they cannot handle it. I give you an example. When I ask if they can calculate the timelike form factors of hadrons (protons, pions, kaons) which we measure so painstakingly, they tell me that they cannot handle quarks in Euclidean time. Is this really true that there are things which cannot be measured on the Lattice?

<u>C. Davies</u> Yes. Lattice QCD calculations serve a number of useful purposes but they were never intended to put experimentalists out of business, more as away of providing good tests of QCD against experiment in hadron physics. It is true that there are also only certain things that we can calculate.

<u>K. Seth</u> Thank you for being honest! (smiles).

<u>L. Maiani</u> I have a comment: I think that the purpose of Lattice Gauge Theory is to make explicit what QCD can say, but certainly this does not imply that experimentalists have to go away. What we would like to do is validate QCD by comparing the results of lattice calculations with experiments. Christine Davies was very honest, but even if things such as timelike form factors and multiquark resonances were measured on the lattice, this certainly should not prevent the experimentalists from challenging such predictions. Consider charmonium: this is a case in which potential models in principle should work. We can compute everything, and yet we find different things by doing experiments. This is what is meant for discovery.

<u>K. Seth</u> There are other cases where I would very much like to have help from Lattice. For example, two-photon decays of charmonia. In the leading or-

der this is a pure QED process. QCD comes in in terms of strong radiative corrections. Unfortunately they are only available at the one loop level, with corrections as large as 100%. Obviously, these cannot be trusted. Can Lattice help?

<u>C. Davies</u> There have been exploratory calculations at Jefferson Lab on charmonium two-photon decays and it is certainly on the list of things that we can do better. Potential models can do well for bottomonium and charmonium but when we look in any detail we find discrepancies with experiment for a given potential, especially if we are not allowed to readjust the parameters, and if we look at decay rates as well as the spectrum. Lattice QCD calculations can provide a big improvement in accuracy here, which is important because the experimental results are very accurate. And we can also predict heavy-light physics with no additional parameters (because we are doing real QCD).

<u>L. Glozman</u> First I would like to make a comment on a statement by our chairman and by prof . Ynduráin that quark models work extremely well. It might work well for spectroscopy of the ground state, but we know that it fails for excited states. My second point concerns mass generation, confinement and chiral symmetry breaking. Heavy quarks do not allow the study of chiral symmetry. To address these issues it is important to consider light quark spectroscopy, which is not well represented in the plenary program at this Conference. Moreover, light quarks have probably an impact on the understanding of the QCD phase diagram.

<u>U. Wiedner</u> I would like to correct a statement that hadron machines are not very useful for spectroscopy. For instance Antiproton proton machines yield the most precise charmonium states.

<u>R. Faccini</u> I haven't said they did not contribute, but, simply, that they importance is limited.

<u>U. Wiedner</u> Panda experiment at Fair will address this problem Theorists should tell us the precise tetraquark spectrum, would be good if lattice and models would come together in order to give some guidance to the experiments.

J. Lee Franzini I think we have lots of light quark presentations, in particular from DAFNE. This is in response to Glozman comment. I also have a question to Christine: can lattice calculate $g - 2$?

C. Davies There are lattice calculations addressing the hadronic contribution, still exploratory, led by Tom Blum at BNL. The time scale is hard to estimate since it is a difficult calculation.

F. J. Ynduráin Lattice results for the $g - 2$ are not for tomorrow, and it will also be difficult to improve on the naive models for light by light scattering.

L. Maiani I would like to come back to Juliet's concern. This problem is going to be solved in a different way. You want to know $g - 2$ to a high precision to understand if there are deviations from the Standard Model. But if such deviations are there, the LHC will see the new particles. So I think LHC will see such effects before we solve the light by light scattering, which is an interesting problem, but after all I agree with what Paco said, it is not for tomorrow.

D. Bugg I would like to follow up to Glozman's remark. We would like much more data. Statistics on charmonium order of hundred events after ten years. Many of these big detectors are now running to the end of present experiments. Big detectors should go in a pion beam. If you do so you can collect an enormous statistics. You need a polarized target, and you can get roughly one million event per day, and all good events. You can cover the entire mass spectrum up to 2.5 GeV in one year. I would like to see JPARC or other machines with a pion beam do such an experiment. Beam intensity is 'trivial'. All of the baryon and meson spectroscopy up to third excitations could be calculated in a couple of years run.

P. Faccioli In this discussion it has been recognized the importance of understanding the interrelation between Quark model and QCD. Other models have been examined in the past few years, and we have learned that dynamical symmetry breaking produces a dynamical mass.

E. Klempt Chiral symmetry breaking is certainly responsible for mass genera-

tion, but how about constituent quark mass for the excited states? I also agree with Bugg, that we need new data. But we can also use the available data from B-factories. It is very important that people publish the data in such a way that everybody can use them for further analysis. We (Crystal Barrel) have set up WEB pages from where you can get lots of information.

L. Maiani I this point I feel I would like to make a comment. I think the table shown by Faccini [the table was still displayed on the screen, note of the Editor] is illuminating, and helps answering a previous question about guidance from theory. Guidance from theory is difficult to get, if you do not have data to start with. The question is, how long it is going to take to fill all the 'grey boxes' in the table, i.e. all gap in the spectroscopy, and which machines can do that? Are the present facilities enough or not?

K. Seth The problem is that so far these new states have been populated mainly by B-decays or double charmonium production at the B factories. Even with several hundred femtobarns of luminosity in most case the event statistics is terribly small. They would need several attobarn to improve the situation in any significant way. In one case, for $X(3872)$ the Tevatron has shown that if a completely different way of reaching these states can be found, one can make a real difference. We just have to find other ways than the B-factory ways of populating these exotic states.

L. Maiani Can Belle do that?

K. Seth I do not know what Belle's plans for the Super-B Factory are, However, at CLEO we are trying to access these states. But the cross sections are very small. New projects like PANDA should certainly try.

E. Pallante Another comment on $g - 2$, what might be feasible on the lattice is the prediction of the hadronic component. From an experimental point view is more important to reach an agreement between e^+e^- and τ data.

S. Paul This is a comment on Bugg's statement. I would like to comment that Compass is still collecting data and I would like to comment to Eberhardt that

LEP has already thought us how to combine data from different collaborations. And this requires people from different collaborations to work together.

R. Faccini Theorists always want more data. The main challenge involves the D's, there we would need at least one hundred times more statistics.

R. Mussa Beauty factories are perfect tools for discovery, but detailed studies ask for dedicated facilities. How high in energy will BES-III go? Will it be possible to scan the $Y(4260, 4350, 4660)$ states recently discovered and discussed at this conference? BES-III has good chances to contribute to these studies. Concerning $p\bar{p}$ experiments like Panda, so far we have no evidence of $X(3872)$ coupling to $p\bar{p}$, or to any other baryon-antibaryon pair. Only the detection of the $X(3872)$ decay to any baryon-antibaryon pair (for instance, η_c preferentially decays in lambda antilambda) would indicate that we have a realistic possibility to study the newly discovered exotic states in a $p\bar{p}$ formation experiment.

S. Glazek One main point of discussion is why quark model works, and if lattice can help with understanding that. The major point is how quarks and gluons lump into constituent quarks. In standard approaches one has nontrivial ground states to explain. This question prompted Wilson and others to develop a light-front approach to QCD. I would say, lattice is not enough: once we have lattice data we need some theory to interpret it.

L. Maiani Concerning constituent quarks, it seems to me that the audience is divided in two parties, one has very clear idea about them, the other has not. So I suggest that they get together and discuss, and one part explain to the other what to do. Speaking for myself, I am in the middle: there are things we do understand. Concerning lattice, this is a field theoretic approach and when we extract the masses from the propagator, this is a sound procedure which does not need any further interpretation. Would Christine like to comment on this?

C. Davies I do certainly agree.

S. Eidelman This is again on muon $g-2$, and the need of more data to resolve

the discrepancy between τ and e^+e^-. There is no real problem, but still there is a puzzle to be resolved, but luckily we also see the outcome of the data analysis from different groups, Kloe and Novosibirsk, from e^+e^- coming together, and also new data from the τ decays in two pions from Belle where we see that our results for the hadronic contributions to $g-2$ are in agreement with previous results from Cleo. Upcoming new machines, one already being commissioned in Novosibirsk, continuing a low energy e^+e^- scan, up to 2 GeV, 10 to 50 times better statistics, and of course I very strongly vote for DAFNE2. At the same time Belle and BaBar will help with τ decays. There is also a theoretical question, as to whether we understand well enough the SU(2) breaking corrections in τ decays.

F. J. Ynduráin You can fit e^+e^- data and τ data together just allowing a slightly different ρ mass and width. So I do not think there is any real disagreement to worry about.

H. Koch This is a comment on the relevance of the proton antiproton physics for the search of new particles. It is true that so far we haven't seen a coupling of $p\overline{p}$ to these new states. In BaBar there might be a good chance to observe thee states.

K. Seth I would like to add one remark on the $p\overline{p}$ possibilities. Of course, a new machine should try what it can., but the unfortunate fact is that the coupling of these states to $p\overline{p}$ is going to be very small. We have already seen that at Fermilab E760/E835. The pQCD prediction, a la Brodsky, is that the coupling is inversely proportional to the eighth power of the quark masses. So, the cross sections for populating heavy quark states are going to be very much smaller than found for the light quark states studied at LEAR.

L. Maiani One should keep in mind the difference between between the cross section in $p\overline{p}$, the other is the inclusive production in $p\overline{p}$ collisions. $p\overline{p}$ at Tevatron, we know the order of magnitude of the cross section. If we go to FAIR, there is a matter of energy. Any comment from FAIR?

U. Wiedner For Production of J/ψ we have about 120 nb.

<u>L. Maiani</u> As now it is time to conclude, I have basically three points.

- We seem to be worried about applications of QCD to experiments. This is a very interesting message, with all the limitations QCD might have. Feedback from theories to experiments for these kind of states will be very interesting, but do not expect too much, since we do not know how to solve QCD, we can make guesses, but sometimes guesses might be wrong, although of course this does not kill the model.

- Coming to the data, my personal worry is, which are the machines which will produce the data? A Super$B$-factory might take some time. So I hope the issue can be addressed at $p\bar{p}$ colliders, at the Tevatron, or maybe at FAIR.

- Finally, I think that a workshop on quark constituent masses will be a very appropriate outcome of this discussion.

This report was partly based on transcriptions of the recording, necessarily shortened to remain within a reasonable page limit. The Editors thank all the participants, apologize for any mistake and/or incomplete rendering of their contributions, and hope that they nonetheless managed to convey the basic messages and the feeling of a very lively discussion.